The Work of the Bureau of Standards

By P. G. AGNEW
Physicist, Bureau of Standards, Washington, D. C.

ALL of the more important countries have found it necessary to set up some governmental agency for standardization and research work in physics, chemistry and technology. These institutions have exerted and are exerting a profound economic influence, in the past by reducing the confusion in weights and measures from which commerce and industry have largely emerged, and at present in clarifying allied subjects in which more or less confusion still exists. In the more highly developed institutions, more complex problems, such as standards of quality, are being undertaken, which frequently involve extensive physical and chemical research. Such problems are of great importance to extensive branches of industry.

The three countries in which the organization has gone farthest are Great Britain, Germany and the United States. The first institution to be established on a modern scale was the Physikalisch-Technische Reichsanstalt, which was established in 1887. This is a standardizing and research institution of the highest class. Germany has two other institutions, the Normal-Eichungs Kommission, which has control of the weights and measures of trade, and the Materialprüfungsamt, which, as the name implies, is devoted to testing and investigation of materials of various sorts. The latter institution is under the control of the state of Prussia.

For many years Great Britain has maintained a Standards Department under the Board of Trade. This has charge of standardization and inspection service and general administration of trade weights and measures. The most important British institution of the kind is, however, the National Physical Laboratory which was founded in 1898 by the Royal Society and has since been maintained by it with the aid of governmental grants. Recently, as a part of the reconstruction program in research and standardization, the direction of the Physical Laboratory has been taken over by the Department of Science and Research. Hereafter the work of the two institutions will be unified.

France has the Laboratoire d'Essais, the Laboratoire de l'Électricité, and has made other provision for such work. Plans have been drawn for establishing a strong centralized institution covering the whole of the field. The Department of Communications of the Japanese Government maintains a well equipped research and standardization laboratory. Other countries, including the British Dominions, have similar institutions, although not so extensive. As a result of the war and the innumerable technical problems arising from it, a great interest has been awakened in the type of research and standardization work carried on by such institutions, and there has been a considerable activity all over the world in establishing new institutions for such work, and in strengthening institutions which were already in existence.

Our Bureau of Standards, which was founded in 1901, is the only one of the national laboratories which covers the whole field in a single institution. In a general way it may be said to cover the same field that the British and German institutions do. There is the difference, however, that the bureau is not charged with the general legal administration of weights and measures laws, but its facilities are to be used for the improvement of weights and measures, for securing uniformity in state legislation concerning weights and measures, and in the administration of such legislation.

The work of the bureau is very extensive as may be seen by reference to the Annual Report of its activities which covers more than 200 pages. The work falls under three general heads: Standardization, Research, and Testing.

Manifestly it will be possible in a brief review of its activities to mention only a few of the more typical phases of the work. Moreover these will be chosen primarily to illustrate the activities of the bureau in the field of standardization. Some idea of the scope of the work may be obtained from the divisions into which the administration of the bureau is divided:

I. Electrical
II. Weights and Measures
III. Heat and Thermometry
IV. Optics
V. Chemistry
VI. Engineering Instruments
VII. Materials Testing
VIII. Metallurgy
IX. Ceramics

Each of these divisions does standardization, research and testing work in its own field. The standardization work has primarily to do with the scientific and technical side rather than with what may be termed commercial or industrial standardization.

FUNDAMENTAL STANDARDIZATION

One extremely important phase of the bureau's work is that in connection with the fundamental units of measurement and their realization by means of concrete standards. One not intimately familiar with the work is likely to think of it as having been already accomplished. This, however, is far from being the case, and much important and painstaking work requiring the highest type of scientific training and experience remains to be done even in the older subjects. There are important fields in which only the merest start has been made.

The scope and the difficulties of the problems involved in such fundamental standardization are not generally realized. To secure agreement on the definition of a unit a great deal of investigation and discussion involving many conferences is necessary. After the theoretical definition of the unit has been agreed upon, it has to be translated into some form of concrete primary standard. Means must be provided for translating measurements from the primary standard to the reference standards of testing laboratories, and these in turn to the reference and working standards of manufacturers and others who must use them.

Unfortunately there is a widespread popular notion that the bureau's work is limited to standards of length and mass, but it has to do with many other units and standards of a fundamental nature, for example: the electrical units of resistance, electromotive force, current, inductance and capacity, the temperature scale, the calorie, standards of wave length, candle power, color, and others. Work on fundamental subjects involves coöperation with various technical organizations, including national laboratories of other countries.

During the early years of its existence a great deal of work was done by the bureau on the fundamental electrical standards, and international agreement was reached on some of these. Much, however, remains to be done. For example, final agreement has not been reached upon the details of the primary standards involved in the measurement of electric current itself.

Standards of Candle Power

One of the most important phases of the bureau's work on fundamental standards has been that in connection with standards of candle power. When the bureau took up the subject, the unit of candle power used by the gas industry differed by some 2 per cent from the unit in use by the electric light industry. The units in use in various countries showed similar differences. There was not, and in fact there is not now, an American national legal standard. After years of the most careful work, not only a national but an international agreement on the unit was reached. (This does not include Germany whose standard differs by 10 per cent from that of other nations.) The actual concrete standard by which the unit of measurement is realized is a group of carefully selected and seasoned electric incandescent lamps which are burned under the most carefully specified conditions. Groups of these lamps were prepared by the bureau and furnished to the national laboratories of France and England for comparison with similar groups used in those institutions. While nominally the different countries base their units on different standards, in practice the units are maintained by these groups of electric lamps by means of which international agreement was obtained. This work has had a profound and far-reaching influence upon the development of the industry. While the cost of the work ran into many thousands of dollars, the expenditure is wholly insignificant in comparison with the economic advantages that have accrued to innumerable branches of the national industry.

The Temperature Scale

A similar problem has been undertaken in connection with the standard scale of temperature. As in other cases involving standardization of a fundamental nature, a vast amount of difficult research work has had to be done, and more remains to be done. The international Bureau of Weights and Measures had already done considerable work on the subject when it was actively taken up by the national laboratories. As in other cases the necessary research work ramifies into many other fields; for example, in the case of the temperature scale, work was necessary in the theory of radiation, in the electrical conductivity of metals; thermoelectric properties of metals, the compressibility of gases, and many other fields of physics.

When the European war broke out, considerable progress had been made toward an international agreement on the temperature scale. While such an agreement had not been reached in detail, the bureau has been able to establish the temperature scale with accuracy.

The work of the bureau on the higher ranges of the temperature scale has been extremely important in the development of technical pyrometry, the measurement of high temperatures for industrial processes. A single industrial application is sufficient to indicate the great economic importance of the subject. In the steel industry there are many processes of heat treatment in which fairly accurate temperature control is necessary. Formerly many millions of dollars of steel products depended upon the trained eye of the foreman in estimating the temperature of steel from its color. The accurate scientific measurement and control of temperatures in such processes is one of the major improvements which have been introduced into the steel industry in the last few years. There are many other branches of industry in which the need of accurate temperature measurement and control is of far-reaching economic importance.

Color Standards

There are several important branches of industry in which the way has not been blazed for scientific standardization. One important industrial subject in which very little progress had been made until the last few years is the question of standardization of color. At first we might be inclined to think that this would not be a subject of sufficient importance to warrant an extensive scientific and technical investigation. It is, however, a subject of real importance to a large number of industries which have no direct connection with each other, and a brief indication of the bureau's work in this subject may be of interest as typical of the type of work which can and should be done in other subjects. The bureau has been appealed to by the following interests for assistance in technical problems which the interests concerned were not in a position to solve without assistance:—Railway officials, refiners of oils, paint and varnish manufacturers, tobacconists, manufacturers of chocolate, dairymen, physiologists, psychologists, illuminating engineers, dealers in dyes, lithographers, packing companies, teachers of art, paper manufacturers,

textile manufacturers, ophthalmologists, state governments, and the following departments and bureaus of the national government: Bureau of Chemistry, Navy Department, War Department, Government Printing Office, Post Office Department, Bureau of Engraving and Printing, Bureau of the Census, Bureau of Entomology, Bureau of Lighthouses, and the Interstate Commerce Commission.

The following are some of the difficulties which were to be met: The fundamental physical principles upon which scientific systematization and standardization could be built up were well understood only by a very few experts who had given attention to the subject; there was no agreement as to definitions, nomenclature, and methods, even among these experts; those most vitally interested from an industrial or commercial point of view failed to comprehend at all the fundamental principles involved; pseudo-standards, empirical methods having no definition or even description other than the maker's name were in wide use, and without any attempt at systematic standardization; there was a lack of reliable quantitative fundamental data on the physical, physiological, and psychological factors involved; precision instruments suitable for the measurements were not available. By the aid of a small congressional appropriation, and with the coöperation of a few technical laboratories, most encouraging progress has been made in the removal of some of these difficulties. But much remains to be done.

In addition to the work which has been accomplished in the fundamentals of the subject, progress has been made in applications to several important industries, for example, in the specifications of the yellow tints in butter and oleomargarin, in the absorption of glasses intended to protect the eyes from harmful radiation, which was undertaken at the request of the American Medical Association, in the measurements of transparency of paper and tracing cloth, and in the color grading of cotton-seed oil, which is commercially sold according to its color.

This work may be taken as a typical example of the important technical and economic results to be obtained from a sound program of standardization. It furnishes a broad scientific basis enabling an entire industry, including both consumers and producers, to speak the same language. The advantages accruing

to a single branch of industry may, normally, be expected to be many times greater than the cost of the fundamental work which will eventually find application in scores of industries.

GENERAL STANDARDIZATION AND TESTING

The bureau does a large amount of general standardization, research and testing work which is of a decidedly less fundamental character than that which has just been described, although it is of great, and often of more immediate importance to the industries concerned. One of the important lines of work is the testing of reference standards for other standardizing laboratories, both public and private. Many manufacturers periodically send their reference standards to the bureau for test.

Relation to the Government

The bureau serves as a testing laboratory for the various government departments. Many of them are engaged in the design, construction and specification of a great variety of special apparatus in which the principles of physics and chemistry are involved. The bureau is constantly called upon to serve as a consulting and research institution for these departments.

TECHNICAL ASSISTANCE TO REGULATORY BODIES

The bureau is not charged with the administration of regulatory laws of any sort. It does, however, coöperate closely with state and local regulatory bodies in technical matters, serving as an agent in technical investigations and to a less extent in an advisory capacity. The coöperation is, however, by no means limited to the official bodies. Opportunity is offered for the fullest coöperation with the industries concerned; the purpose is to be helpful alike to the official bodies, to the industry, and to the general public. During the early part of its existence this work was limited to coöperation with weights and measures officials. Gradually such coöperative work was extended. During the last few years the problems of safety in electrical installation and of service standards in public utility work were taken up actively. Certain phases of this work have grown rapidly and have had a very important influence in securing improvements and uniformity in such standards.

Weights and Measures

The bureau coöperates actively with state and local authorities charged with the administration of weights and measures laws. Under its auspices an annual conference of such officials is held. In this manner much has been accomplished in securing improvement in and uniformity of weights and measures legislation and in the improvement of the administration of existing laws and regulations. This is a subject of great economic importance. Men who are thoroughly familiar with the subject estimate that the direct loss to the general public through the use of fraudulent weights and measures amounts to tens of millions of dollars annually. Probably the indirect loss to the industry and to the general public arising from such unsatisfactory conditions as exist is equally great.

A few years ago the bureau took up the testing of railroad track scales. Until this time no official tests of such scales had been made, although the total annual freight revenue based upon weighings made with such scales amounted to over two billions of dollars. More recently the bureau was called upon to test mine scales in a case of a threatened strike. Very serious errors were found in all the scales examined in the region in question, not a single one being within the tolerance allowable in such work. All the errors were found to be against the miners. As a result of the investigation, indictments were returned in the local courts and several convictions followed. The result was that the threatened strike was averted. By the aid of a small Congressional appropriation, investigations are being made in other regions. As is well known, the question of accuracy of mine scales is a prolific source of labor disputes in the coal mining industry. It is thus seen that this work offers opportunities of a very great national service in helping to eliminate an important source of labor disputes, to say nothing of the extensive economic savings made possible thereby.

Safety Standards

As a result of coöperation with organizations seeking to introduce greater uniformity and efficiency in rules providing against hazards to persons in the electrical industry, the bureau undertook the preparation of a national electrical safety code. The prepara-

tion of this code extended over four years and involved by far the most comprehensive investigation of the entire subject that has ever been attempted. It has now been adopted in one form or another, in part or in whole, by some twenty administrative bodies, and many others have taken favorable action upon it, thus leading toward uniformity in the various states. A new edition of the code is now in course of preparation. The project is necessarily a continuing one to keep abreast of changing conditions in the industry.

A gas safety code has been in preparation for some time but its development was very seriously retarded by war conditions. The bureau is preparing to undertake the preparation of a series of industrial safety codes. This will be done in very close coöperation with a considerable number of organizations which are directly concerned. The importance of thoroughgoing investigation of this whole subject looking to the development of satisfactory codes which may be adopted with reasonable uniformity throughout the country, is evidenced by the large number of industrial casualties. The number of such casualties occurring annually is roughly equal to our casualties during the war. There are annually four hundred thousand accidents sufficiently serious to be recognized by compensation boards, and of these accidents eighteen thousand are fatal.

Public Utility Service Standards

The bureau is in active coöperation with state commissions, municipalities and public utilities in the study of technical problems forming the basis of service standards. The work includes scientific and engineering research, study of the methods of testing and inspection employed by utilities, municipalities and commissions, and the preparation of specifications regarding the quality of public utility service. Service standards for gas and for electric light and power, published by the bureau, have received wide recognition and have been very effective in introducing uniformity into the different states and municipalities. In one important phase of street railway work, namely the electrolysis of underground structures, the most extensive investigation ever made of the subject has been carried out during the last few years and the bureau publications on the subject are now recognized as the standard authority on the subject. Investigations are being

carried on in these and allied subjects, the most important of which is the scientific and technical basis for telephone service standards.

EFFECT OF THE WAR ON THE BUREAU'S WORK

The demand for the services of the bureau in connection with military work was far greater than its facilities could supply, although special grants for military purposes were made by Congress, by the President, and by the War and Navy Departments, totaling more than $2,000,000. The bureau undertook work on some two hundred problems having a direct, military bearing and it is safe to say that probably more than four-fifths of the work of the bureau was directly for the Army and Navy Departments. The staff was more than doubled.

Only a few of the more important undertakings can be mentioned. The largest single problem was the testing of master gages for practically the entire munitions production. By master gages is meant the reference gages used by manufacturers and inspectors. Over one hundred persons were employed in the work. Some idea of its economic importance may be gained from the statement, which had been made on reliable authority, that at least two American firms, who contracted for large quantities of munitions in the early part of the European war, each lost several millions of dollars by rejections, the primary reason being inaccuracy of gages. The accuracy required in this work was decidedly greater than that ordinarily met with in machine-shop practice. This work has an intimate bearing on many industrial problems in normal times. For example, the bureau is taking an active part in the work of the American Screw-thread Commission (the chairman of which is the director of the bureau). General standardization of gages will probably play a more important rôle in the future than it has in the past on account of industrial standardization.

Another extremely important undertaking was the bureau's contribution to the aircraft program. A laboratory was constructed for the test of airplane motors under conditions of temperature and pressure met by airplanes at high altitudes. A wind tunnel was constructed for determining experimentally the wind resistance of various airplane parts. Extensive investiga-

tions were made on problems in connection with aviation instruments. The work of the bureau on airplane fabrics led to the introduction of an entirely satisfactory cotton substitute for linen when supplies of the latter were found to be inadequate. The ignition systems of airplane motors, technical questions having to do with the dopes used in treating airplane fabrics, gases for filling military balloons, and other aircraft problems led to extensive researches.

There were many other important investigations undertaken for the military departments which will have a permanent effect upon the industries. One of these was the development of a new kind of pot used in the production of optical glass, which is an industry new to America, and in the establishment of which the bureau played an important part. Another was the assistance rendered the War Department in simplifying and standardizing materials for purchases.

National research councils have been established in all of the Allied nations, and provision is being made in all these countries, particularly in England and the British Dominions, for the governmental promotion of research and standardization on an extensive scale.

Analogy between the work of the bureau and that of the Agricultural Department has frequently been drawn, it being held that the bureau should eventually occupy somewhat the same position with respect to the technical manufacturing industries that the Department of Agriculture does to the agricultural industry. Physical and chemical research and scientific and technical standardization are playing a more and more important rôle in the manufacturing industries. Consequently it seems inevitable that the federal government should, in this way, do more and more to foster these industries.